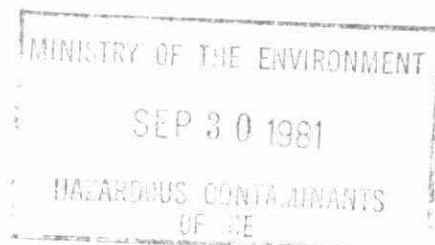




LYSIMETER AND COLUMN TESTING OF SOLIDIFIED INDUSTRIAL WASTE FROM THE UPPER OTTAWA STREET LANDFILL, HAMILTON

January 1979



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Ministry
of the
Environment

The Honourable
Harry C. Parrott, D.D.S.,
Minister

Graham W. S. Scott, Q.C.,
Deputy Minister

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LYSIMETER AND COLUMN TESTING
OF SOLIDIFIED INDUSTRIAL WASTE
FROM THE UPPER OTTAWA STREET LANDFILL, HAMILTON

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Ontario Ministry of the Environment

January, 1979

Air Quality Section
Project FCD 7806

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INDUSTRIAL WASTE FROM THE UPPER OTTAWA LANDFILL,
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NOTE

Solidified waste used for the above study was obtained from a batch of material prepared by K.D. Enterprises under what was believed to be normal operating conditions for the process. However, it is known that the material can be highly variable in composition, hence the material selected for the tests may not be representative of waste "fixed" at other times by this company, it's successor Frontenac Chemical Waste Service Ltd. or other companies engaged in waste solidification. The conclusions and recommendations from the study should, therefore be used with reservation and express the views of the writer only and are not necessarily those of other agencies of the Ontario Ministry of the Environment.



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September 20, 1979

INTRODUCTION

A "solidification" process for the stabilization of liquid industrial wastes was developed by David Krofchak Ltd. and Ontario Liquid Waste Disposal Ltd. Solidified material was tested for leachability with distilled water in small diameter columns using an "unsaturated" flow procedure developed by the Ontario Ministry of Environment (OMOE) Sediment and Soils Laboratory, Toronto. Results of the laboratory evaluation and field tests were reported by the OMOE Industrial Section, Pollution Control Branch in 1976. It was concluded that the bulk of the common heavy metals were retained in the processed material. There was concern for the disposition of the material because of the high dissolved solids content of the leachate.

The principle of the solidification process is to bond heavy metals with excess of lime and high silica containing materials such as clay. K.D. Enterprises Ltd. are using the process at the Upper Ottawa Street Land-fill site.

A number of samples of K.D. solidified product and laboratory solidified product were tested for leachability using tap water (pH 7.3) and/or Hamilton Harbour water in columns, beakers and flasks by the Department of Metallurgy and Materials Science, University of Toronto (McAndrew and Muthuswami, 1978). Tests were run for up

to 31 days. Results were in essential agreement with those of the earlier evaluation of the Ministry of Environment.

Subsequent to the 1976 OMOE study samples of solidified waste from the site have periodically been tested for leachability with distilled water at the OMOE Sediment and Soils Laboratory under standardized conditions of unsaturated flow and three 24 hour "cuts". Leach quality was variable, e.g. copper and zinc concentrations exceeded the Ontario effluent guideline of 1 ppm (OMOE, 1973) for two leach tests conducted in December 1977 and April 1978.

The Upper Ottawa Street landfill site is located adjacent to Redhill Creek. The site has been used for both domestic and industrial waste for the past 20 years. Only a small portion of the site is used for waste solidification. Sampling stations along Redhill Creek leachate springs and surface run-off were monitored by the OMOE in the spring of 1978 (OMOE, Technical Support Section 1978). It was concluded that metals are not escaping from the landfill site in appreciable quantities. Pollution of the creek from the landfill was limited to the products of the organic breakdown of domestic refuse (high BOD and ammonia). There was concern that there could be increased leachate generation when the landfill reaches field capacity.

The Ottawa Street site is to be closed in 1980 and it is planned to continue solidification operations elsewhere if deemed to be environmentally safe.

It was thought worthwhile, therefore, to conduct leaching tests using larger quantities of solidified material for extended periods of time using acid rain water and an organic leach liquor generated from compost produced by the Resource Recovery Centre, Toronto. It was thought that the latter would give some indication of the effect of

leachate from domestic refuse and, in addition, provide some evaluation of the compost as a potential cover for landfill sites. Suction filters acting as lysimeters were installed at three levels to sample water passing down the column. Bottom drainage was also collected. Leaching tests were also conducted with small columns using distilled water, 0.005N DTPA (diethylenetriaminepentacetic acid) and 1N ammonium acetate (pH 4.8) for comparison with the large column and to assess the effects of organic and weakly acidic leaching conditions.

EXPERIMENTAL

A lysimeter test was started on October 6, 1978 and terminated January 10, 1979. Solidified waste freshly prepared at the K.D. Enterprises site at the Upper Ottawa Street landfill site was poured into a 15 cm ID Plexi-glass column to a depth of 75 cm above a 3 cm layer of washed sand. A modified "Swinnex" type suction sampler (lysimeter) with 9 cm Whatman GF/C fibre glass collector and .45 μ M Millipore membrane similar to that used by Stevenson for sampling soil water (Stevenson, 1978) was located 5 cm above the sand layer ("deep" sampling point). The Tygon tube from the sampler was taken up through the column to an aspirator bottle. A second suction sampler was installed 52 cm above the sand layer ("mid" sampling point). A drain line was installed at the base of the column.

The material was wet and still warm when received. No attempt was made to drain off the free water. A total of 38.8 lb (17.6 Kg wet weight) was used for the test (6.3 Kg dry weight). A 1.25 cm layer of Celite was placed on top of the mass to act as a diffuser. The leach liquor was contained in an inverted 5 litre plastic bottle. Flow rate was controlled by the use of a narrow bore Technicon tube (blue-orange). A small hole drilled in the base of the supply

bottle permitted liquid flow. Rain water collected in the Haliburton area by the OMOE Limnology and Toxicity Section was used as leach liquor (acid rain). Two to five litres were added every 24 hours except for periods when some drying was allowed to take place.

Aliquots were withdrawn from the two suction samplers ("mid" level and "deep") using 40 cm Hg suction applied by hand vacuum pumps. Leachate draining through the sand layer at the base of the column ("bottom sample") was also collected.

Nine "cuts" were collected with the addition of a total of 24 litres acid rain water. Ten pounds (4.54 Kg) of dry 1/2 inch screened compost from the Resource Recovery Centre, Toronto was then placed on top of the column to a depth of 55 cm and the leaching continued using acid rain water to Cut 14. Distilled water acidified to pH 4 with carbon dioxide was then used until Cut 24 when the test was terminated. A suction filter was installed near the base of the compost to sample leachate from the compost. Glass fibre filters (9 cm diam) were placed on top of the compost to act as diffusers.

The small columns were set up using the OMOE Sediment and Soils Laboratory standard procedure (100 g waste leached with 300 ml cuts under "unsaturated flow" conditions).

Leachate cuts were analyzed for metals by ICAP (Inductively Coupled Argon Plasma) and AAS (Atomic Absorption Spectrophotometry).

RESULTS

The treated waste, identified as S8-41-2, was analyzed for heavy metals by AAS and ES-ICP following dissolution by hot HCl/HNO₃. Of interest were the high concentrations of zinc, chromium and iron (from waste pickle liquor) and high calcium (from added fixative).

TREATED WASTE - K.D. ENTERPRISES

Sampled October 5, 1978

ug/g dry weight (ppm)

Zinc	62,000
Calcium	140,000
Chromium	6,000
Iron	7,000
Manganese	660
Copper	750
Nickel	620
Lead	32
Cobalt	5.8
Cadmium	2.2
Sodium	3,100
Potassium	1,100

Moisture content 64 per cent

The liquid waste used in the process was a clear, very dark green solution. The liquid was analyzed by ES-ICP using 100X and 50X dilutions. The approximate concentration (mean values) was as follows:

LIQUID WASTE FOR SOLIDIFICATION

<u>Metal</u>	<u>mg/l</u>
Aluminum	220
Calcium	340
Cobalt	80
Chromium	4,700
Copper	650
Iron	14,000
Magnesium	150
Manganese	150
Nickel	430
Strontium	2
Titanium	8
Zinc	8,800

The rain water used for the leach tests was obtained from the Haliburton area. The average composition is as follows:

HALIBURTON RAIN WATER	
COMPOSITION (mg/l) *	
Iron	0.10
Zinc	0.014
Lead	0.015
Aluminum	0.10
Manganese	0.012
Copper	0.002
Nickel	< 0.002
Calcium	1.0
Magnesium	0.15
Sodium	0.30
Potassium	0.10
Silicon	0.30
Sulphate	6.0
Chloride	0.25
Total Phosphorus	0.025
Dissolved Phosphorus	0.01
Total Kjeldahl Nitrogen	2.5
Ammonia	0.9
Nitrate	0.5
pH	4.0
Conductivity mMhos	50
Alkalinity mg/l	0

* Data supplied by W. Snyder, Limnology & Toxicity Section, OMOE.

I. LYSIMETER TEST

The solidified waste as received was green in colour and paste-like in consistency. The bulk of it rapidly turned brown although patches remained green for extended periods.

There was an indication of low surface infiltrability (ponding of leach liquor) during Cut 2 and channelling became a problem. The addition of Celite helped although channelling continued but less obviously.

The initial leachate collected by the suction filters was strong yellow in colour. Later cuts were pale yellow. Very little leachate was collected from the bottom take-off, probably because of the bulk of it was removed by suction during the earlier cuts. It is of interest to note that the yellow colour could be removed by shaking with Darco G-60 carbon (indicating it was organic).

The "cuts" from the different sampling points were analyzed for several parameters. Some of the data was plotted graphically (Appendix).

pH

The pH remained almost constant at 12.1 "deep" in the column while leaching with acid rain for the first five cuts, then dropped off more rapidly. The pH appeared to drop to a new level of pH 8-9 on the addition of compost and continued to drop to pH 7 by Cut 19.

The pH was more erratic higher in the columns but showed the same general trend.

Prior to the introduction of the compost the pH of the leachate from the bottom of the column was about 2-3 pH units lower than the "deep" leachate and dropped off more rapidly. It appeared to stabilize after the addition of the compost with values up to 1 pH unit higher than those for the suction filter sampling points. The initial pH of the compost was 8.3.

CONDUCTIVITY

Conductivity, initially very high ($16-20 \times 10^3$ mMHos), dropped off relatively rapidly for all sampling points with similar values for the "mid" sampling point and the bottom drain. Conductivity (and hence dissolved salts) appeared to stabilize in later cuts following the use of organic leachate and carbonated distilled water. Conductivities of under 2×10^3 mMHos were obtained for the bottom take-off and about $4-5 \times 10^3$ mMHos for the "mid" and "deep" tube-offs.

CALCIUM

The concentration of calcium in the leachate, particularly at the deep suction sampling point, was initially very high (>1500 ppm), dropping to about 600-700 ppm by Cut 19. Lower values were obtained for the bottom take-off, with concentrations decreasing from about 1100 ppm to about 100-300 ppm.

IRON

Very little iron was leached by the acid rain water with concentrations of < 1 ppm at the different sampling points. Higher concentrations (up to 16 ppm) occurred in the bottom leachate following addition of the compost whereas low values continued to be obtained at the suction filters. Concentration of iron in the bottom leachate decreased rapidly, however, levelling out at about 1 ppm.

TOXIC METALS

Zinc concentrations decreased with successive cuts from about 6 ppm to < 1 ppm at the "deep" filter using acid rain water. Lower concentrations were obtained for the bottom take-off in early cuts with intermediate values for the "mid" filter. Higher concentrations (up to 6 ppm) were obtained for the bottom take-off following addition of the compost but dropped

off rapidly to < 1 ppm.

It is of interest to note that initial leachate from the compost contained about 8 ppm Zn.

A similar pattern was observed for nickel. Concentrations at the "deep" suction point subsequent to the first cut were appreciably higher than those for the "mid" suction. Levels were below 0.5 ppm in later cuts following addition of the compost.

Copper and chromium were both low (< 0.5 ppm) in later cuts. Lead and cobalt concentrations were below the detection limits for AAS (.06 ppm Pb, .08 ppm Co).

STEADY STATE CONCENTRATIONS
IN LEACHATE (DEEP SUCTION FILTER) mg/l

Zinc	0.1*
Nickel	0.3*
Copper	0.3*
Chromium	0.2*
Calcium	600
Iron	0.3
Aluminum	0.3
Strontium	1.5
Magnesium	< 0.1
Manganese	< 0.1
Titanium	< 0.1
Cadmium	< 0.1
Arsenic	< 3
Lead	< 0.06*
Cobalt	< 0.08*

* AAS analysis; other data by ES-ICAP

WATER QUALITY PARAMETERS

Cuts Nos. 1 and 9 from the "deep" suction filter were analyzed for water quality parameters. Of interest was the high sodium and chloride and sulphate concentrations (200 ppm Na, 4000 ppm Cl and 1300 ppm SO₄ in Cut 1.). Ammonia and phenols were also high (240 ppm and 750 ppb, respectively). There was some drop but concentrations were still high in Cut 9.

CONCENTRATION IN LEACHATE (mg/l)		
"DEEP" SUCTION FILTER		
	Cut 1	Cut 9
Nitrite	0.33	0.40
Nitrate	45	41
Chloride	4020	2600
Sulphate	1350	1400
Sodium	2000	1100
Phosphate	0.02	0.02
Potassium	230	140
Phenols	0.75	0.38

II. COLUMN LEACH TESTS

Small column leach tests were conducted with acid rain water followed by 0.005N DTPA and with 1N ammonium acetate adjusted to pH 4.8 with acetic acid. In each case 100g of the material was placed in a column and 300 ml of the extractant dripped through the column every 24-48 hours.

RAIN WATER LEACH

Concentrations ppm							
Cut No.	pH	Cond. mMhos	Ca	Fe	Zn	Ni	Appearance
1	11.8	7,500	700	.4	.3	.9	Clear, yellow
2	11.5	3,000	440	.4	.3	.3	Clear, colourless
3	10.8	2,900	440	.2	<.1	.5	Clear, colourless
Rain water	3.7	50	.06	.01	<.1	<.1	

Notes- Low infiltrability in Cut 2. Head of water built up but eventually flowed through column.
- ES-ICAP data. Not digested

DTPA LEACH

Concentrations ppm									
Cut No.	pH	Cond. mMhos	Ca	Fe	Zn	Ni	Cu	Pb	Appearance
5	11.3	9200	1500	160	47	2.5	1.8	0.2	Clear, colourless
6	10.2	10800	1600	120	89	2.2	0.4	0.1	Clear, colourless*
7	9.5	10600	1400	80	130	1.9	0.3	<.06	Clear, colourless*
.005N DTPA	7.8	8500	430**	1.1	0.3	.02	.13	.01	

Notes - Low infiltrability. Head of liquid built up before passing through column.
- ES-ICAP data. Not digested.
- Cuts with DTPA followed water leach.
- ** Calcium chloride used in reagent.
- * Small amount of white precipitate.

AMMONIUM ACETATE LEACH

Cut No.	pH	Concentrations ppm					Appearance
		Ca	Fe	Zn	Ni	Cr	
1	9.4	7400	.1	800	5.8	.2	Clear, light blue
2		3300	19	650	13	15	
3		3100	19	670	12	13	
AM Acetate	4.8	5.5	1	1.2	<.1	.2	

Notes - ES-ICP data. Digested with HCl/HNO₃ prior to analysis

DISCUSSION

The treated waste tested contained higher concentrations of zinc and chromium but less iron than the mixes evaluated by the OMOE in 1976, McAndrew and Muthuswami in 1977 and an April 1978 sample analyzed by OMOE (S26-164). The calcium content was of the same order as for the previous mixes. Nickel and copper were present in higher concentrations.

TREATED WASTE

	Metal concentrations%			
	OMOE 1976	McAndrew Muthuswami	OMOE April 1978	October 1978
Zinc	0.5-2.8	1.6-4.3	3.9	6.2
Chromium	.01-.14	.09-.22	.22	0.6
Iron	2.8-3.9	2.2-5.3	3.0	0.7
Calcium	11.6-14.5	11.6-16.5	18.	14.
Nickel	.004-.01	.003-.015	.01	.06
Copper	.003-.004	.006-.046	.006	.08

Laboratory leaching conditions with acid rain water in the small column were slightly more severe than the distilled water tests used previously by OMOE. The initial pH of the leachate, however, was higher in the current tests than in 1977 or early 1978 tests by the Ministry. Values were closer to those obtained in the 1976 study. It is of interest to note that relatively more nickel was leached than in previous tests, probably because of the higher content in the fixed waste. DTPA following the water leach mobilized appreciable amounts of iron, zinc and nickel. Acidified ammonium acetate leached even more zinc and nickel. Of interest was the liquid blue colour of the leachate.

In the large column leaching with acid rain water resulted in higher concentrations of zinc and nickel in the leachate, particularly for the "deep" suction point. Addition of the compost (plus acid rain water) generated a liquor with nearly 8 ppm Zn and 3 ppm Ni. However, after the first few cuts leachate from the column was low in both metals. Leachate from the bottom of the column was similar in appearance to the leach liquor from the compost (dark coloured; highly dispersed colloid content) and, initially had elevated concentrations of nickel and zinc. There was, therefore, strong indication of leach liquor by-passing the column, supported by visual observation of localized channelling and cracking resulting from shrinkage and/or swelling of the mass.

Swelling eventually led to rupture of the column at Cut 24! The suction filters, fortunately, gave a better indication of soil water moving by capillary action through the 9 cm diameter cross-suction of the fibre glass collectors.

Of interest was the difference for values of parameters at the "deep" and "mid" suction sampling points, particularly during the initial stages of leaching. Values were higher for the "deep" suction point for parameters except iron (pH, conductivity, calcium, zinc and nickel), indicating

the effect of path length on pollutant generation. Concentrations at the two points were similar for later stages of leaching. Iron is of interest in that concentrations at the suction filters remained low throughout the test although "bottom" concentrations following application of compost were initially high (most probably due to by-passing through cracks and channels as for zinc and nickel).

It is not thought that the use of acid rain water and acidified distilled water rather than distilled water had any significant effect on leachate generation in the lysimeter test, principally because of the large buffering capacity of the system. The large drop in pH (from 12 to 9) between cuts Nos. 8 and 10 may be attributed to relatively rapid leaching of hydroxyl groups. Addition of compost appeared to have little effect on leaching through the mass of material by capillary movement, as indicated by suction filter data.

The same general conclusions about the leaching potential of the solidified waste with rain water could be drawn from the small column and the lysimeter test (high pH, high conductivity, leaching of calcium and nickel) although concentrations were lower. The organic component in the leachate from compost did not appear to have the complexing power of DTPA, perhaps partly because it was colloidal rather than a true solution. The leaching effect of DTPA and particularly N acidified ammonium acetate indicates high leaching potential under adverse conditions which could develop in a landfill site. It is felt that the high leachable calcium content has a protective effect only against the mild conditions of a water leach for a long period.

McAndrew and Muthuswami estimated on the basis of 80 cm/annum rainfall for the Hamilton area using leach data with tap water that 2.1 years could be required for the complete dissolution

of calcium with longer periods for other elements (e.g. 49,000 years for iron). They commented that some of the rain would run off rather than percolate and some absorbed would evaporate hence these values could be considered as minimum limiting values. They did not calculate values for toxic metals such as zinc and nickel.

Using the lysimeter data of the present study and a steady state concentration of calcium in leachate of 600 mg/l it is estimated that 490 cuts of 3000 ml would be required to leach the calcium out of the column. This can be calculated to a figure of 1.5 years/cm bed depth (cf McAndrew and Muthuswami's estimate - 2.1 years/cm). A similar estimate is obtained calculating from the data for the small column in the present study using 440 mg/l Ca steady state leaching (2.1 years/cm).

If a 0.3 mg/l Ni steady state concentration is assumed for the lysimeter study until all the calcium is leached it is estimated that only 1.1% of the nickel originally present will be leached, with about the same percentage for copper. A smaller percentage of the zinc will be leached (about .004%). It can be assumed that these metals would leach at an accelerated rate once the calcium has been dissolved (2-4 years/cm bed depth; about 60-120 years per foot).

Although massive release of toxic metals can be expected to be delayed for many years steady release of low concentrations will probably occur as indicated by the steady state data. The sum of these concentrations may approach or exceed the OMOE guideline criteria of 1 mg/l for industrial effluents. In the lysimeter test the sum of concentrations of Zn, Ni, Cu and Cr was about 0.9 mg/l.

Column leach test with material from the Ottawa Street landfill site in 1977 and early 1978 indicated that variable leach results can be obtained as discussed earlier. In

most cases concentrations of toxic metals in the leachate were acceptably low although in some instances higher concentrations were obtained, indicating need for caution (e.g. Zn 2.3 to 2.8 mg/l for material sampled December 1, 1977 and Cu 6.0 to 3.5 mg/l for April 28, 1978).

CONCLUSIONS

1. Correct "fixation" of some types of industrial waste can prevent or at least delay mobilization of toxic metals (Zn, Ni, Cu and Cr) by rain water.
2. Leach tests in small columns can be used as indicators of waste stabilization in such materials although greater reliability of data can be obtained from larger scale extended duration lysimeter tests with suction filters.
3. Leachate quality (in terms of toxic metal concentration) for liquid passing through the material through the fine pores (to the suction filters) was generally satisfactory for water leach. High chloride, sulphate, sodium and phenols could be more important considerations.
4. Migration through channels in the material could partially negate the attenuation effect of the material on leachate from a cover material (such as compost).
5. Compost from the OMOE Resource Recovery Centre generated a leachate with high organic colloid content. Initial leachate had relatively high concentrations of Fe, Zn and Ni whereas later production had low concentrations.
6. "Fixed" material is not stable to leaching conditions stronger than water leach such as the presence of organic chelates and acid conditions.

RECOMMENDATIONS

1. Small scale column leach tests should be conducted periodically with water, DTPA and acidified ammonium acetate. The solidified material should also be analyzed for total toxic metal, calcium and iron content.
2. Consideration should be given to modifying the leach test procedure to ensure that the effect of channelling is minimized, such as by the use of fibre glass collectors and suction filters or hollow fibre tubing.
3. If practicable, suction filters should be placed in drill holes in the solidified material at the landfill site to permit monitoring of the quality of water moving through the material, as a more realistic alternative to laboratory column and lysimeter tests.
4. Cores from drill holes in solidified waste should be taken periodically and analyzed to ensure the presence of an adequate supply of calcium. If not, consideration could be given to mixing in additional lime containing material to replace that lost by leaching.
5. Care must be taken in the disposition of solidified waste in that it should not be exposed to acidic or some types of organic leachate.

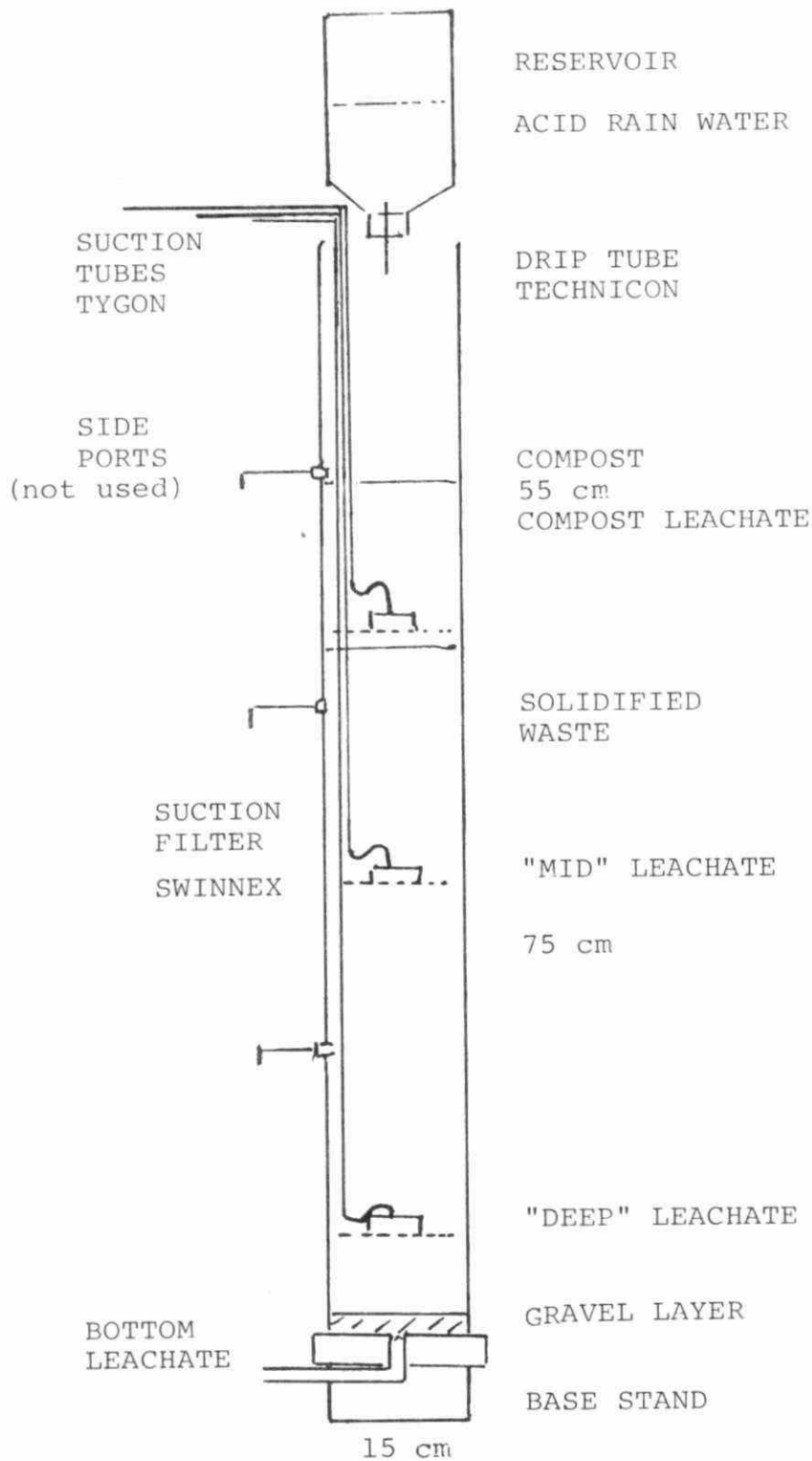
ACKNOWLEDGEMENTS

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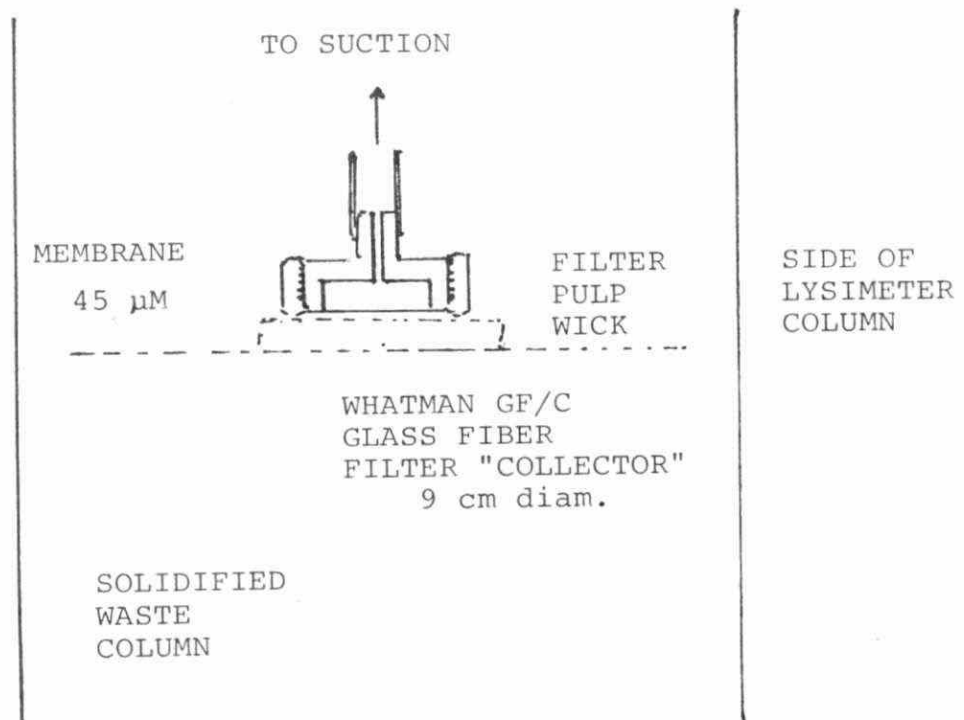
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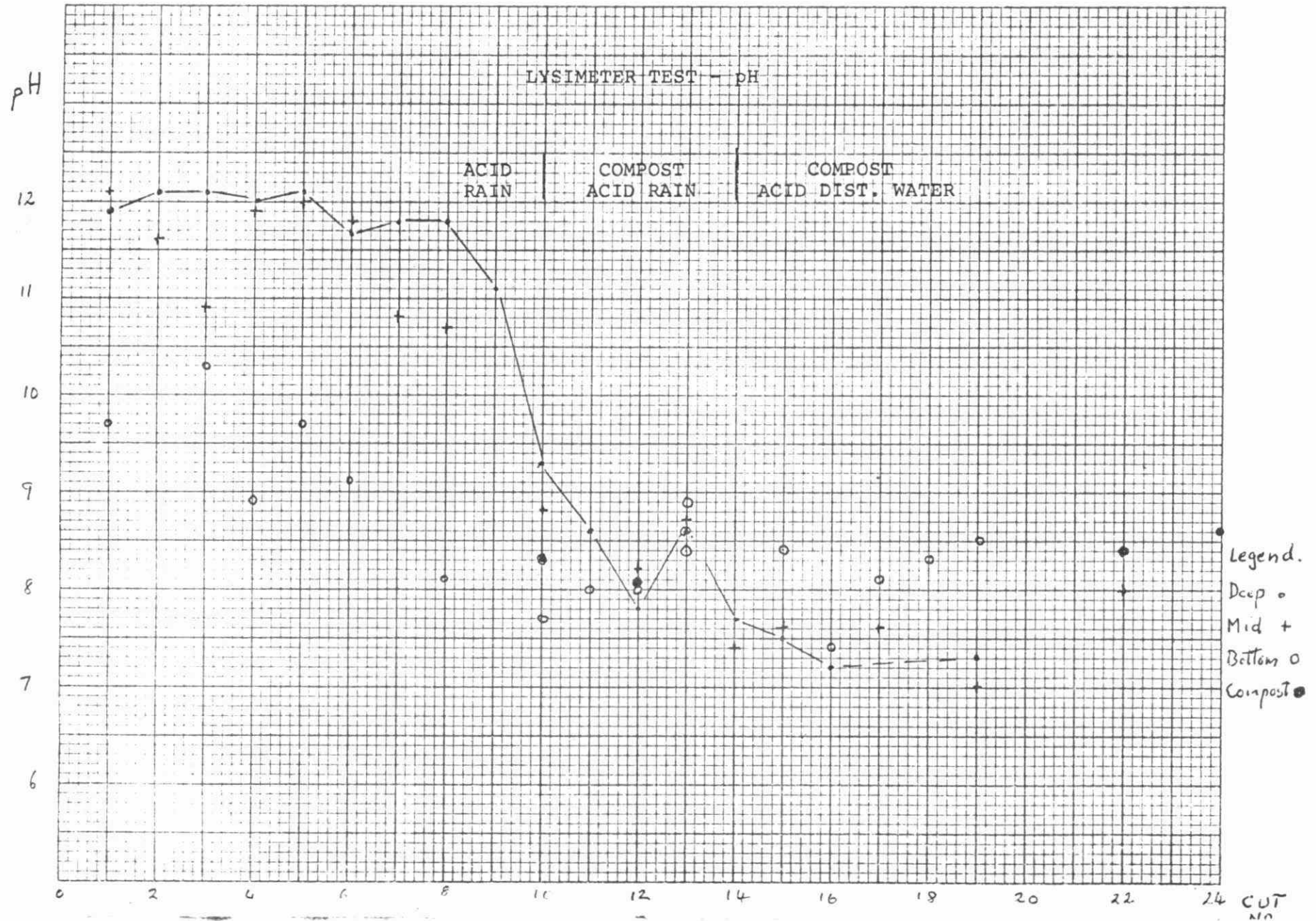
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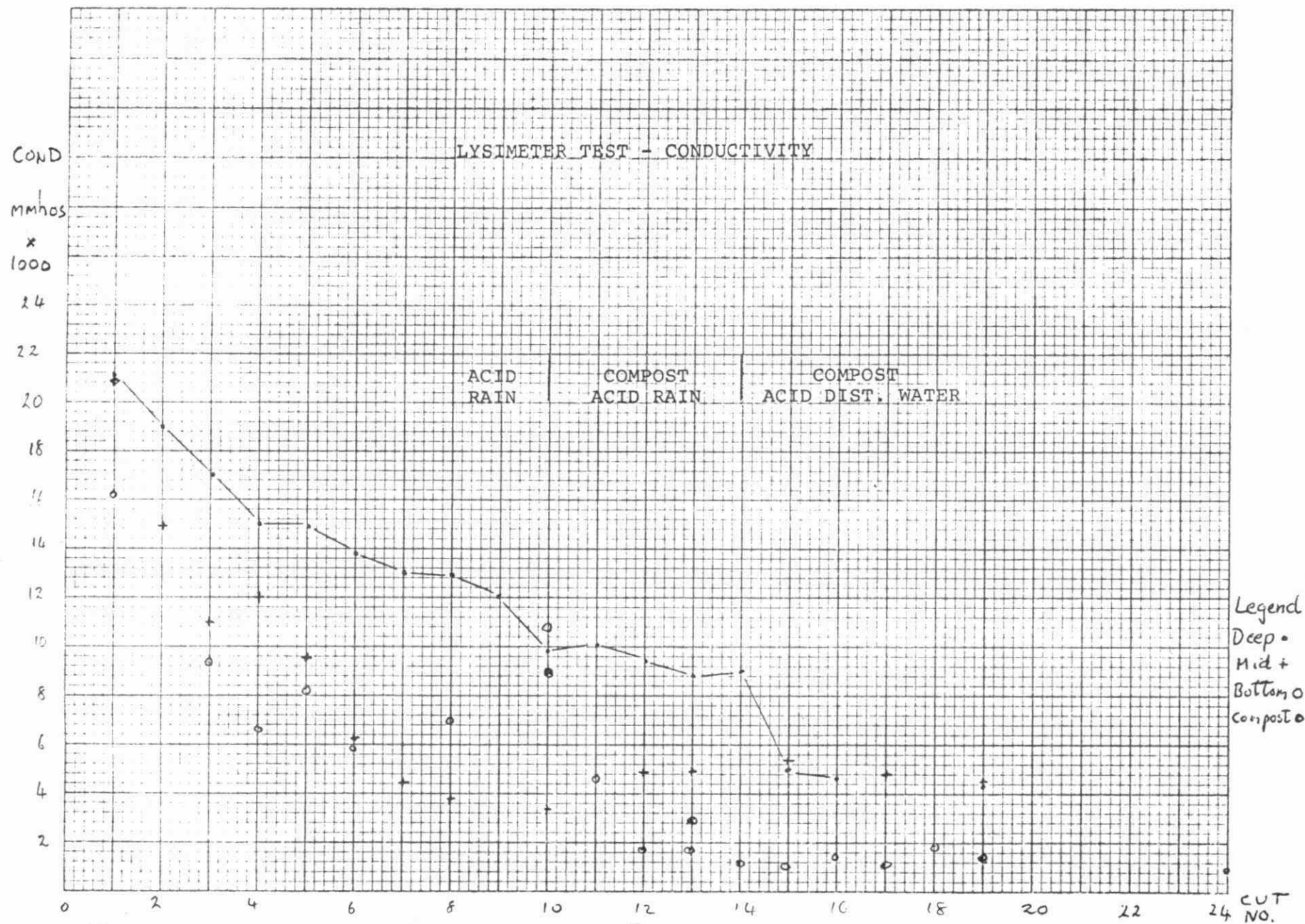


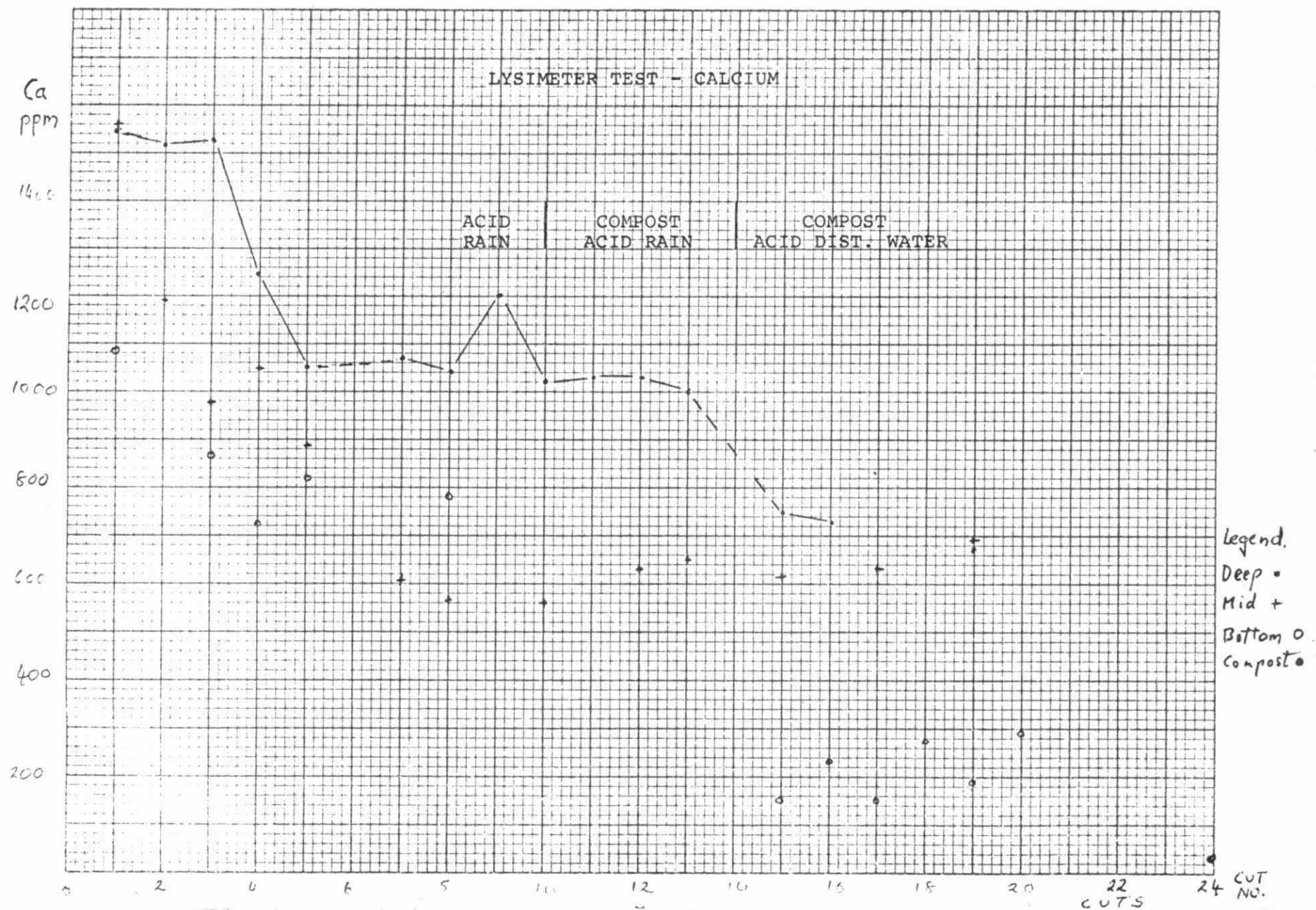
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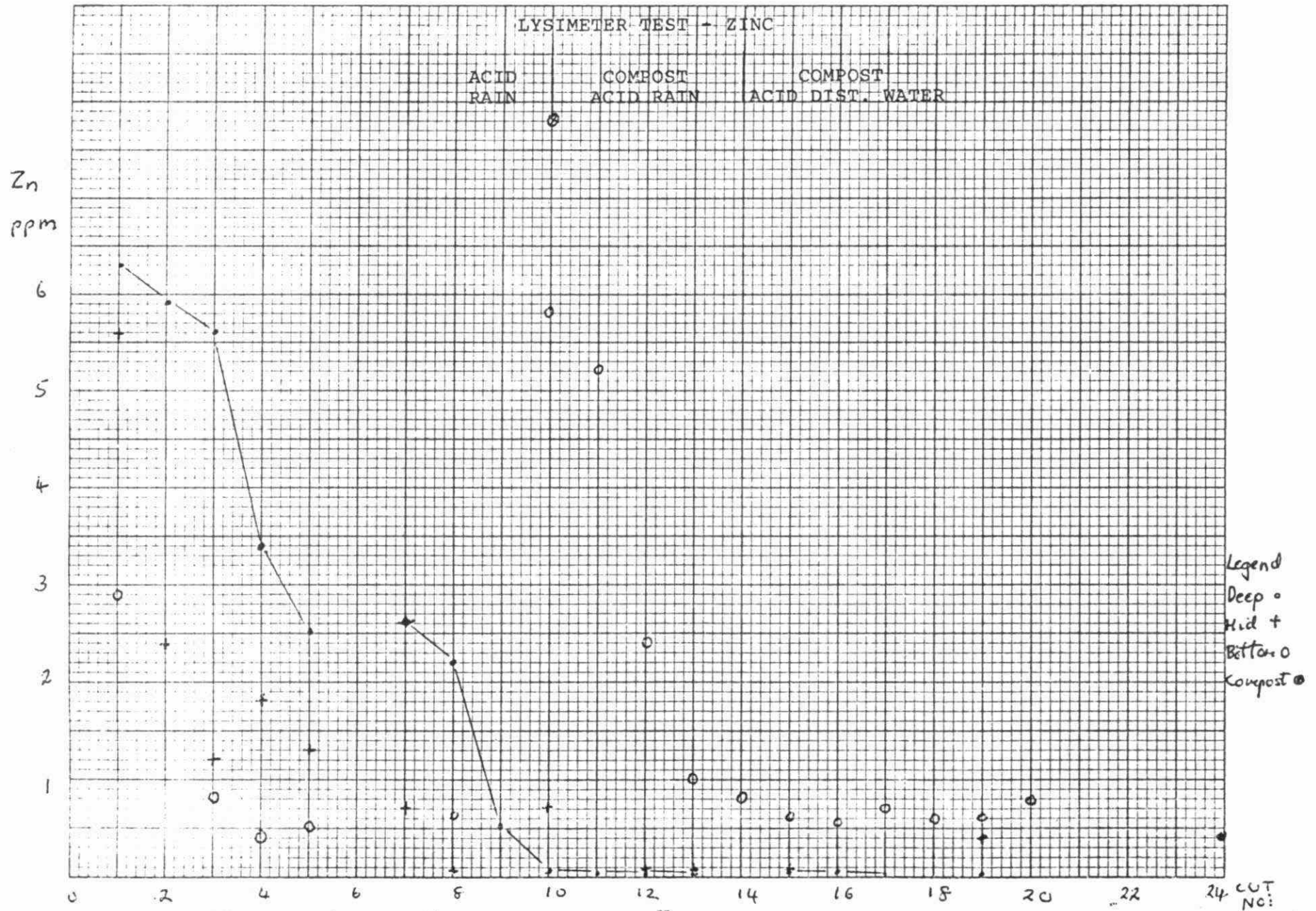


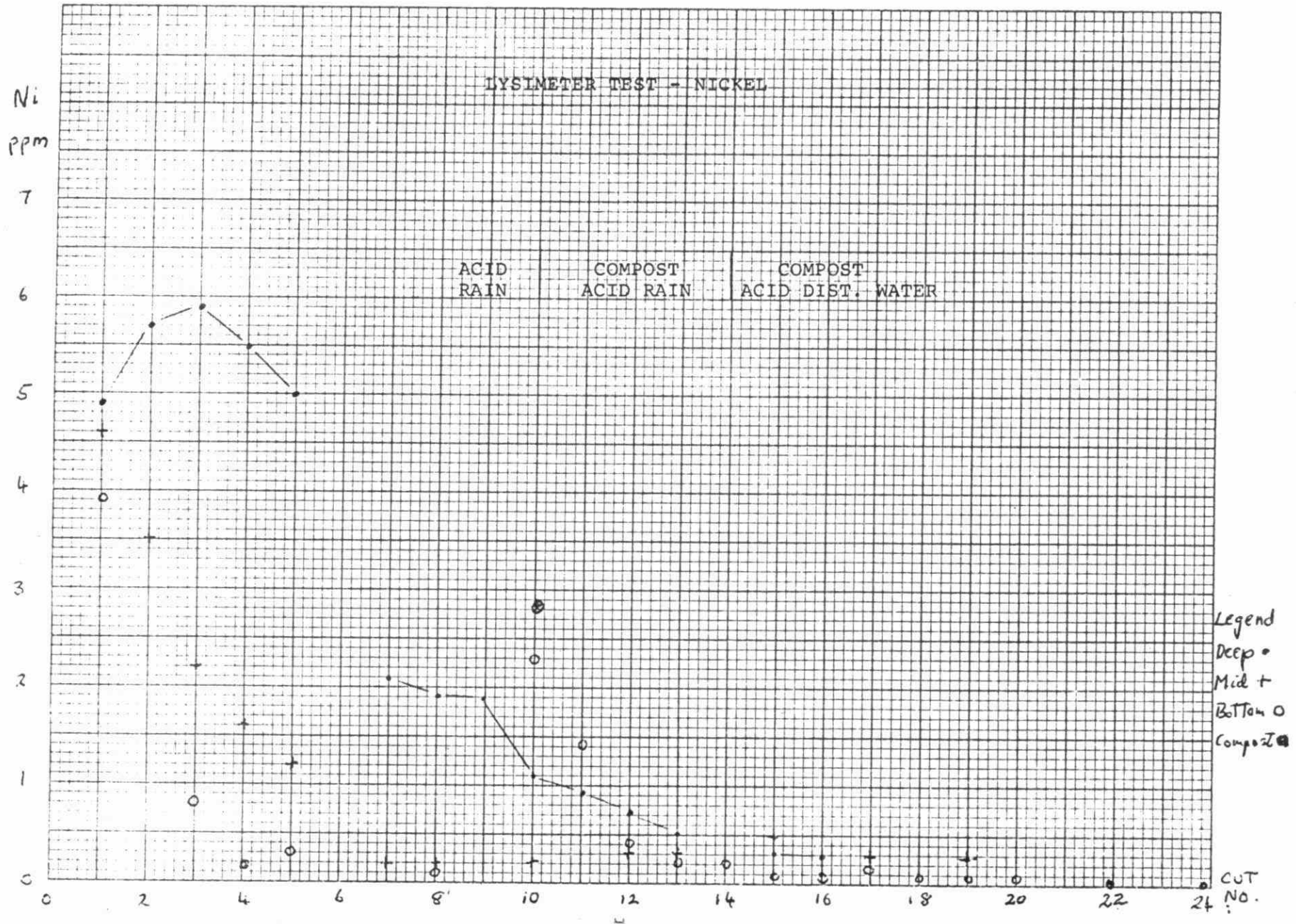
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